THE CHARACTERISTICS OF VARIOUS TYPES OF CONGLOMERATES[1]

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In the prosecution of a recent study of the Roxbury Conglomerate (Boston, Mass.), the writer found himself in need of criteria by which to determine the mode of origin of that formation. A critical examination was therefore made of the published descriptions of conglomerates in many parts of the world and belonging to many geological ages, in the hope of discovering characteristics sufficiently marked to distinguish one type from another. The data collected and the conclusions derived therefrom have recently been published in detail.[2] The present paper is a brief summary of the results of the investigation.

Five general types of conglomerate were considered, namely: marine, fluviatile, estuarine, lacustrine, and glacial. In addition to these, another type was studied, commonly known as crush-conglomerate, but really pseudo-conglomeratic in its nature. The fact was recognized that many conglomerates are the product of the combined action of several conglomerate-forming processes, but the results of each process were classified separately.

Among the formations taken under consideration were: the Cretaceous formation of Texas, as described by Hill;[3] the Pottsville Conglomerate; non-marine formations in India, Persia, Great Britain, and the United States; the Devonian of Pennsylvania and Maryland, as described by Willis;[4] the Newark formation as described by Russell;[5] glacial deposits of the Quaternary period in the United States and Europe; ancient glacial deposits in India, Australia, South Africa, and Norway; and crush-conglomerates in the Isle of Man and Argyllshire.

[1] Read before the Geological Society of America, December 28, 1906, New York.

[2] Museum of Comparative Zoölogy, *Bulletin No. XLIX*, Geological Series, 8, 1906.

[3] R. T. Hill, U S. Geological Survey, *Twenty-first Annual Report*, 1901, pt. 7.

[4] Maryland Geological Survey, 1902, Vol. IV, pp. 21–93.

[5] U. S. Geological Survey, *Bulletin No. 85*, 1892.

The data collected from these various sources were arranged in accordance with the following scheme:

Matrix.—Kind of material; size of grains (coarse or fine, uniform or varied); shape of grains (angular, subangular, or rounded); arrangement of grains (orderly or disorderly, well stratified, rudely stratified, or unstratified); cement (argillaceous, siliceous, calcareous, or ferruginous).

Pebbles.—Kind of material; size of pebbles (large or small, uniform or varied, gradation in any particular direction); markings (facets, polish, striation); deformation (distortion, tension cracks, fracture); arrangement (well stratified, rudely stratified, unstratified).

Color.—General tone of the rock; relations to matrix; relations to pebbles.

Characteristics of bedding.—Uniform series grading into finer beds, thickness and extent; variable series (lenses of coarser and finer materials, false-bedding and local unconformities, ripple-markings, sun-cracks, raindrop-impressions, or organic markings), thickness and extent.

Relations to subjacent rocks.—Conformable; nature of the underlying series; unconformable; eroded surface deeply disintegrated; eroded surface of relatively fresh rock unglaciated; eroded surface relatively fresh rock glaciated.

The matrices of the various types of conglomerates have not been very fully described. According to Geikie the small particles of detritus are generally less well rounded than those of greater dimensions.[1] This is doubtless true of all water-laid deposits. The evidence collected appears to show that the matrices of marine conglomerates tend to consist of clean sands fairly well sorted and often cross-stratified. Willis states of beach deposits that the "sand is clean and characterized by marked and irregular cross-bedding."[2] Russell, referring to the incrustation of the grains in certain ferruginous deposits, remarks that if the débris had been deposited in the ocean and exposed to the action of waves and currents, the sands would have been more thoroughly assorted than we now find them, and also that the attrition produced by the waves under such circumstances would have scoured off the incrustation of ferric oxide.[3] Dutton, too, emphasizes the more thoroughly assorted condition of marine sediments as opposed to fluviatile deposits. Of the latter he states that material of all sorts is deposited everywhere, yet with a tendency to

[1] *Text-Book of Geology*, 4th ed., Vol. I, p. 162.

[2] *Journal of Geology*, Vol. I (1893), p. 487.

[3] U. S. Geological Survey, *Bulletin No. 52*, 1889, p. 45.

sorting.[1] Probably the littoral deposits of lakes would approach marine deposits in uniformity of size and arrangement of particles, but with the absence of tides it is doubtful if these characteristics would be in general so highly developed.

Estuarine deposits are seen to consist in the main of mixtures of sand and clay, not very well assorted, but relatively fine. The matrices of crush-conglomerates would doubtless present much diversity in the size and shape, but not in the material, of their particles. Probably glacial deposits display the greatest variation in the character of the finer fragments that constitute their matrices. Fluviatile deposits may often approach them in heterogeneity of material and arrangement, and in angularity of individual particles. One minute distinction may, however, be noticed. In the case of small fluviatile fragments, which are only slightly rounded, the attrition will probably be equally developed on all corners or edges. In the case of similar glacial fragments, as shown by the microscopic study of the Dwyka conglomerate, one edge or corner of a particle may be smoothed or rounded, while other corners or edges remain sharply angular.

The evidence thus far collected goes to show that the pebbles of marine and lacustrine conglomerates tend to be well sorted and well rounded, though they may be subangular in proximity to their sources. Shrubsole, noting the way in which pebbles on a beach slip over each other with the recession of each wave, remarks: "The pebbles become as a rule symmetrical and lose all traces of angularity."[2] Estuarine pebbles tend to be but imperfectly sorted and rounded, and fluviatile pebbles may show all stages from confused heaps to well-stratified beds and from well-rounded forms to almost complete angularity. The difference between marine and fluviatile pebbles is thus expressed by Dutton:

> Attrition [in the fluviatile conglomerates of the high plateaus] is not ordinarily extreme. In most cases it is enough to indicate that the fragments are really abraded, though with no great loss of substance. The stones of subaqueous conglomerates, on the contrary, are always much worn and rounded. Again, the sizes of the stones [in the fluviatile conglomerate] range from a fraction of a cubic inch to several cubic feet; in rare instances to more than a cubic yard.[3]

[1] *High Plateaus of Utah* (Washington, 1880), p. 220.

[2] *Quarterly Journal of the Geological Society,* Vol. LIX (1903), p. 315.

[3] *Loc cit.*, p. 224.

In crush-conglomerates the shapes and sizes are variable, depending on the character of the rocks crushed, and on the character and amount of the deforming force. No doubt the pebbles would often be distorted and contain fracture planes and tension cracks. Glacial pebbles are characterized by variety in composition, size, and shape. Their sizes and shapes may, however, be so successfully imitated by bowlders and pebbles of fluviatile origin that it is only when the fragments are seen to bear the characteristic glacial striae, or to be intimately associated with stones that are so marked, that their glacial nature can be regarded as established. Even here caution is needed; for in landslides or mud flows, or by the action of shore- or river-ice, striated pebbles may be produced, which closely resemble those developed by glacial action.

While the evidence shows that marine conglomerates are sometimes ferruginous, the trend of opinion seems to be that such rocks are not, as a rule, highly colored. According to Russell, observations show that lacustrine sediments are usually not red.[1] The evidence found with reference to the color of estuarine deposits is insufficient to make any general statement; they are, however, often considered to have a tendency toward a red color. Some of the fluviatile deposits studied are shown to have highly colored or purplish zones. Strahan, speaking of the characteristics of continental formations, says they have a common tendency to a red color.[2] Crush-conglomerates, being induced as secondary structures in rocks already formed, partake of whatever color the parent rock may have possessed. Glacial conglomerates, as a rule, appear not to be highly colored, though the Australian bowlder-beds are described as containing reddish-brown members. Red color is therefore not a distinctive characteristic of any particular type of conglomerate formation, but it may be said to be more common in the fluviatile and perhaps in the estuarine types than among the other kinds of conglomerate.

Marine formations have been found to possess, on the whole, the most uniform bedding; while glacial formations exhibit the least developed and perhaps the most irregular stratification. Lacustrine and estuarine formations tend to resemble those of marine origin,

[1] U. S. Geological Survey, *Bulletin No. 52*, 1889, p. 47.

[2] *Quarterly Journal of the Geological Society*, 1897, pp. 143, 144.

while fluviatile formations may be well stratified, or, on the other hand, may so closely simulate heterogeneous glacial accumulations as to make their origin uncertain: witness the discussion of the Midland Pebble Beds of the Old Red Sandstone. Cross-stratification and lenticular masses of coarser and finer material are common in all these types, but in the marine type the long axes of the lenses are more frequently parallel to the shore line—that is, to the original strike of the rocks; while in the case of fluviatile accumulations the long axes of the lenses are parallel to the courses of the stream threads by which they were deposited—that is, to the original dip of the rocks. All water-laid deposits appear to increase in thickness and coarseness toward their source of supply. Marine action, however, tends to produce sheets of relatively uniform thickness over wide areas, while fluviatile action tends to produce interwoven linear bundles of coarser and finer materials, which may attain great thickness in the aggregate over limited areas, but which thin out more rapidly than is the case with marine deposits. Other differences are cited by Strahan in his discussion of continental deposits. He states that the latter are not only unequal, but alternate with erosion, so that fragments of one bed are included as pebbles in another; that they rarely contain marine organisms or such strata as usually compose marine formations, but that drifted plant remains are not uncommon, and that such limestones as occur consist, when unaltered, of amorphous carbonate of lime and not of organic remains.[1] Current markings, sun-cracks, and foot-prints, or other impressions common on exposed mud-flats, are frequent in estuarine and probably in fluviatile or lacustrine deposits, but do not ordinarily occur in marine formations.

In crush-conglomerates no true bedding appears, and all traces of the original bedding may have been destroyed. The bedding of ice-laid deposits is very obscure, and that of fluvio-glacial deposits merges into that of true fluviatile deposits, so that little or no distinction can be drawn.

As regards the relations of conglomerates to subjacent rocks, the main fact brought out by the investigation is that those formations of any age, that have been proved to be glacial, have been found to rest upon striated rock surfaces. The possession of heterogeneous

[1] *Loc. cit.*

Type	Marine	Lacustrine	Estuarine
Matrix	Clean sands, fairly well assorted, cross-stratified, angular to rounded grains.	Similar to marine; perhaps less well-sorted, less clean, and less well-rounded grains.	Fine gravel and sand with muc mud, unsorted, cross-stratifiec angular to subangular grain
Pebbles	Generally local materials, fairly uniform size, well rounded; may be scratched by shore-ice, landslides, etc., but not faceted nor snubbed.	Similar to marine, though perhaps less well sorted and rounded.	Local materials varying in siz and not well sorted, subangula shapes on the whole; marking as in marine.
Color	May be ferruginous, but not usually highly colored.	Similar to marine.	Tendency to red color(?)
Bedding	Stratification generally well marked. Cross-stratification often well developed; in the normal cycle finer sediments encroach upon and overlie coarser materials; sometimes local unconformities, irregularities, lenses, etc., but *more regular* along the original *strike* than along the dip; limestones in the series composed chiefly of organic remains.	Conforms more closely with marine than with fluviatile deposits; in the normal cycle coarse materials encroach upon and overlie finer sediments. Limestones or marls of the series contain remains of freshwater organisms.	Frequent and irregular interbec ding of coarse sands and fine materials; frequent cross-strat fication; ripple-marked an sun-cracked surfaces with o ganic and other imprint mark ings.
Relations to Subjacent Rocks	Conformable or unconformable; nothing especially distinctive of marine action.	Same as marine.	Same as marine.

	Fluviatile	Crush	Glacial
ch d; s.	Sands mingled with finer and coarser material, not well sorted, cross-stratified, angular to subangular grains.	Unsorted autoclastic fragments.	Heterogeneous mass of finer and coarser material, compact, angular grains of minerals and rocks; some fresh feldspar; some grains partially rounded and partially angular.
ze ar gs	Generally local materials of all sizes up to masses of several tons, generally subangular, but varying from rounded to angular; fragments of one stratum included as pebbles in another stratum of same formation. May be scratched by river-ice action, landslides, etc., but not faceted nor snubbed.	Varying size and shape, angular to rounded, showing portions of crests or limbs of folds; fracture planes; tension cracks. Autoclastic fragments.	Generally local materials, but a considerable proportion from distant sources. Little, if any, assortment; all sizes up to masses of several tons. Pebbles faceted, rounded edges, snubbed ends, polished and striated surfaces, with striae generally parallel to long axis of stone, but often showing two or more directions.
	Many not colored, but perhaps tendency to red color.	Depends on parent rock.	Generally dark grayish with bluish and greenish tints, occasionally ferruginous.
d- er ti- nd r- k-	Frequent alternation coarse and fine beds; frequent current markings and oblique lamination; frequent local unconformities; irregularities in thickness and character, lenses, etc., but *less regular* along the original *strike* than along the dip; limestones infrequent, but where they occur and are unaltered, they consist of amorphous carbonate of lime and not of organic remains.	No true bedding, all traces of original bedding may have been destroyed.	Till and corresponding ancient formations, usually not bedded; sometimes obscure stratification, and layers when separated show glazed and striated surfaces; sometimes pockets, lenses, and beds of coarser and finer stratified material with cross-stratification included in the unstratified mass. Fluvio-glacial materials show all gradations from no stratification to well-marked fluviatile type. Marine glacial bowlder beds show well-marked stratification and alternation of coarser and finer beds.
	Same as marine.	Pseudo-unconformity by overthrust faulting or slickensiding.	Rests on striated, smoothed, and polished surfaces of older rocks or older portions of the same formation.

structure, irregular and striated pebbles, while furnishing strong evidence of glacial action, cannot be considered as conclusive proof, for such structures and forms may be produced in other ways. When, however, such forms are found to rest upon a smoothly polished and striated rock surface, the weight of evidence is so great that no other explanation can be accepted.

To summarize: Marine sediments exhibit, on the whole, the greatest uniformity of composition and the most orderly arrangement of materials, while glacial deposits display the opposite characteristics. Lacustrine, estuarine, and fluviatile accumulations attain intermediate degrees of uniformity. Each of the various types of conglomerate possesses features that are shared to some extent by other types. Thus there is no single feature which in itself distinguishes any particular kind of conglomerate. It is only when a number of features of one type are grouped and compared with a similar group of another type that definite distinctions can be made. Such a comparison is attempted in the accompanying tabular summary.